CHAPTER 12

BASIC DIAGRAMS AND SYSTEMS

In the preceding chapters, you learned about hydraulic and pneumatic fluids and components of fluid power systems. While having a knowledge of system components is essential, it is difficult to understand the interrelationship of these components by simply watching the system operate. The knowledge of system interrelation is required to effectively troubleshoot and maintain a fluid power system. Diagrams provided in applicable technical publications or drawings are a valuable aid in understanding the operation of the system and in diagnosing the causes of malfunctions.

This chapter explains the different types of diagrams used to illustrate fluid power circuits, including some of the symbols that depict fluid power components. Included in this chapter are descriptions and illustrations denoting the differences between open-center and closed-center fluid power systems. The last part of the chapter describes and illustrates some applications of basic fluid power systems.

DIAGRAMS

As mentioned earlier in this chapter, to troubleshoot fluid power systems intelligently, a mechanic or technician must be familiar with the system on which he or she is working. The mechanic must know the function of each component in the system and have a mental picture of its location in relation to other components. This can best be done by studying the diagrams of the system.

A diagram may be defined as a graphic representation of an assembly or system that indicates the various parts and expresses the methods or principles of operations. The ability to read diagrams is a basic requirement for understanding the operation of fluid power systems. Understanding the diagrams of a system requires having a knowledge of the symbols used in the schematic diagrams.

SYMBOLS

The Navy uses two military standards that list mechanical symbols that must be used in preparing drawings that will contain symbolic representation. These standards are as follows:

1. *Military Standard, Mechanical Symbols (Other than Aeronautical, Aerospacecraft, and Spacecraft Use), Part 1,* MIL-STD-17B-1.
2. *Military Standard, Mechanical Symbols for Aeronautical, Aerospacecraft, and Spacecraft Use, Part 2,* MIL-STD-17B-2.

Some of the symbols frequently used in fluid power systems have been selected from these two standards and are shown in Appendixes II and III. Appendix II contains symbols from MIL-STD-17B-1. Appendix III contains symbols from MIL-STD-17B-2.

While the symbols shown in the appendixes are not all encompassing, they do provide a basis for an individual working with fluid power systems to build upon. Some rules applicable to graphical symbols for fluid diagrams are as follows:

1. Symbols show connections, flow paths, and the function of the component represented only. They do not indicate conditions occurring during transition from one flow path to another; nor do they indicate component construction or values, such as pressure or flow rate.
2. Symbols do not indicate the location of ports, direction of shifting of spools, or position of control elements on actual components.
3. Symbols may be rotated or reversed without altering their meaning except in cases of lines to reservoirs and vented manifolds.
4. Symbols may be drawn in any size.
5. Each symbol is drawn to show the normal or neutral condition of each component unless multiple circuit diagrams are furnished showing various phases of circuit operation.

For more detailed information concerning the symbols used in fluid power diagrams, consult the above-mentioned military standards. Additional information concerning symbols and the reading of diagrams is contained in *BIueprint Reading and Sketching,* NAVEDTRA 10077-F1.

TYPES OF DIAGRAMS

There are many types of diagrams. Those that are most pertinent to fluid power systems are discussed in this text.

Pictorial Diagrams

Pictorial diagrams (fig. 12-1) show the general location and actual appearance of each component, all interconnecting piping, and the general piping arrangement. This type of diagram is sometimes referred to as an installation diagram. Diagrams of this type are invaluable to maintenance personnel in identifying and locating components of a system.

Cutaway Diagrams

Cutaway diagrams (fig. 12-2) show the internal working parts of all fluid power components in a system. This includes controls and actuating mechanisms and all interconnecting piping. Cutaway diagrams do not normally use symbols.

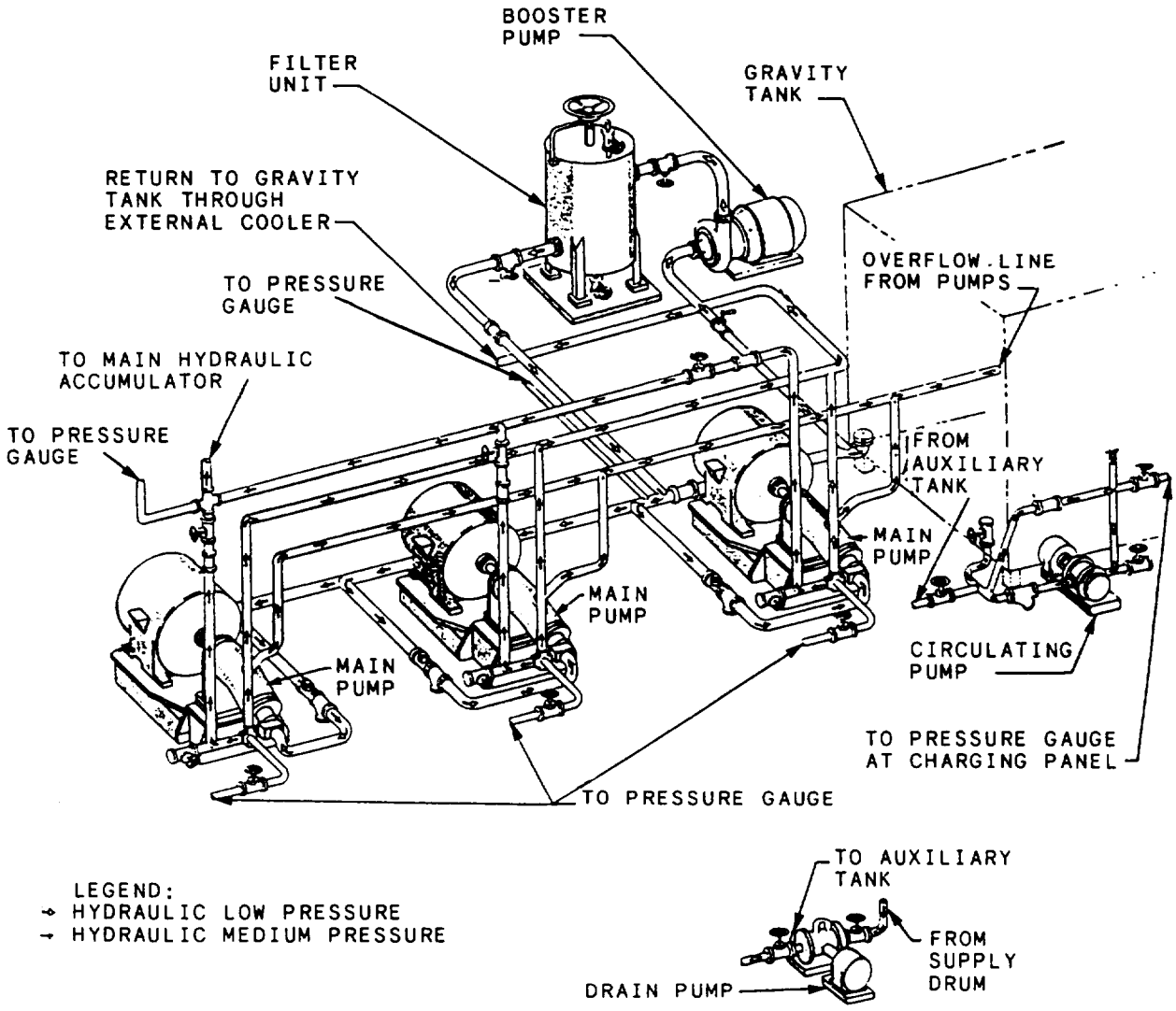


Figure 12-1.—Hydraulic system pictorial diagram.

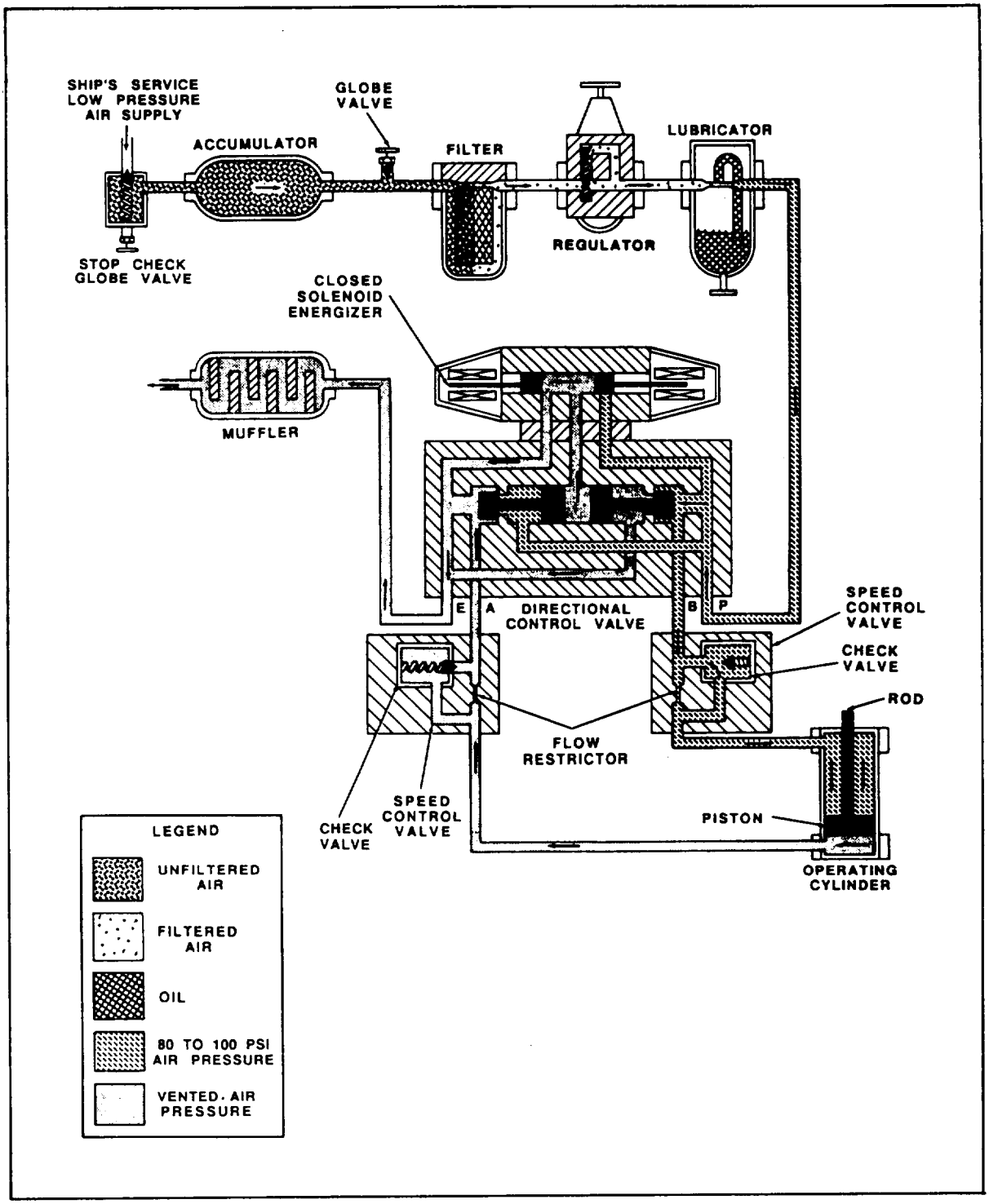
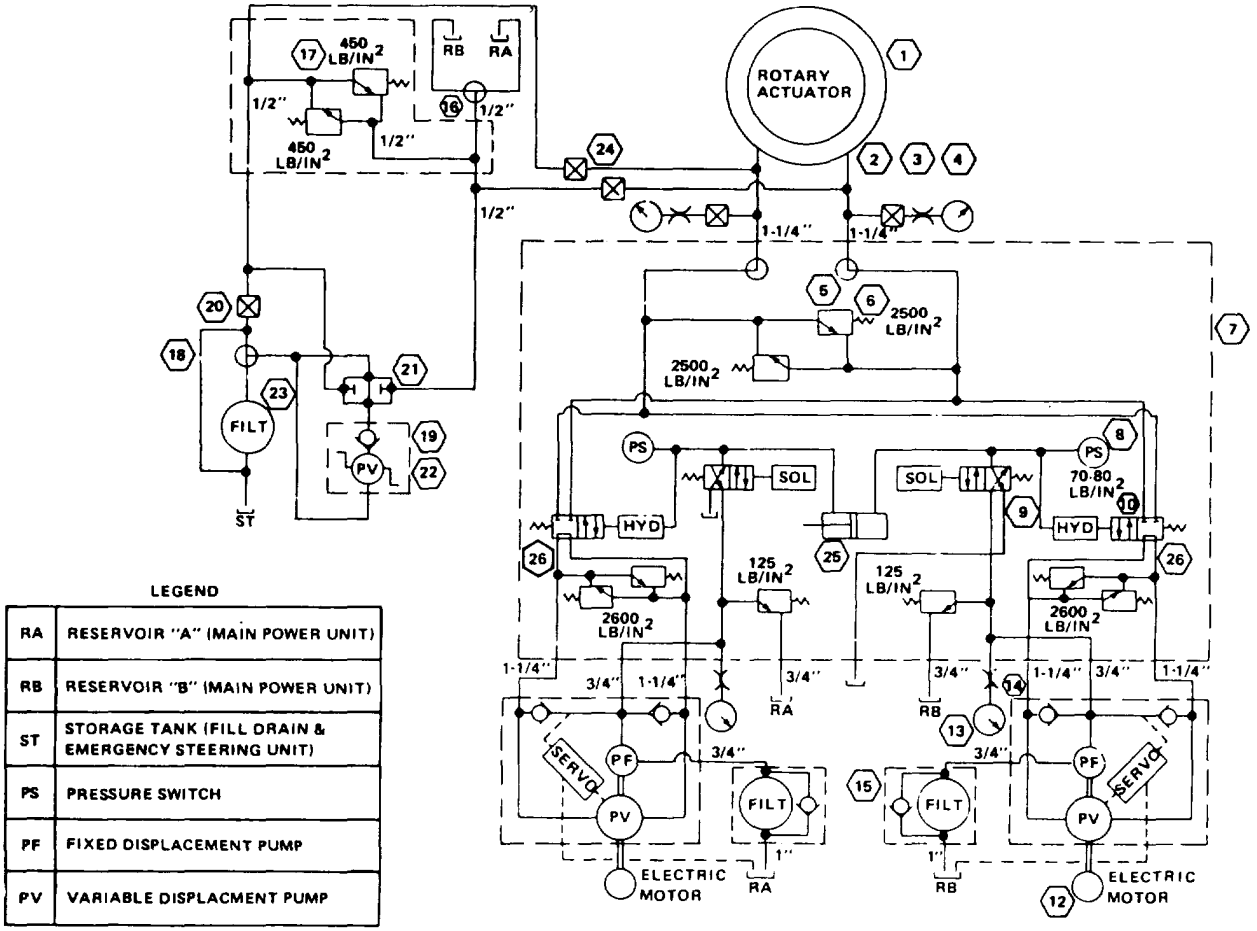


Figure 12-2.—Cutaway diagram—pneumatic.

Graphic Diagrams

The primary purpose of a graphic (schematic) diagram is to enable the maintenance person to trace the flow of fluid from component to component within the system. This type of diagram uses standard symbols to show each component and includes all interconnecting piping. Additionally, the diagram contains a component list, pipe size, data on the sequence of operation, and other pertinent information. The graphic diagram (fig. 12-3) does not indicate the physical location of the various components, but it does show the relation of each component to the other components within the system.



LEGEND	
RA	RESERVOIR "A" (MAIN POWER UNIT)
RB	RESERVOIR "B" (MAIN POWER UNIT)
ST	STORAGE TANK (FILL DRAIN & EMERGENCY STEERING UNIT)
PS	PRESSURE SWITCH
PF	FIXED DISPLACEMENT PUMP
PV	VARIABLE DISPLACMENT PUMP

1. Rotary actuator
2. 1 1/4-inch shutoff valve
3. 0-5000 psi pressure snubber
4. 0-3000 psi pressure gauge
5. Manual 1-inch rotary selector valve
6. Pressure control valve
7. Manifold block
8. 7-250 psi pressure switch
9. 1/4-inch solenoid-operated 4-way valve
10. 3/4-inch pilot-operated 4-way valve
11. None
12. Electric motor (see NOTE)
13. 0-300 psi pressure gauge
14. Servo-operated variable-displacement pump
15. 10-micron filter
16. 1/2-inch manual rotary selector valve
17. Pressure control valve
18. 1/2-inch manual rotary selector valve
19. Common check valve with hand pump
20. 1/2-inch shutoff valve
21. 3/8-inch manual rotary selector valve
22. Hand pump
23. 10-micron filter
24. Shutoff valve
25. LVR/LVP selector cylinder
26. Relief valves

NOTE: Electric Motor is 40 horsepower, 1800 rpm, 440 volts ac, 3 phase, 60 hertz.

Figure 12-3.—Graphic diagram of LST 1182 class hydraulic steering gear.

Notice that figure 12-3 does not indicate the physical location of the individual components with respect to each other in the system. For example, the 3/4-inch, solenoid-operated, 4-way valve (10) is not necessarily located directly above the relief valve (26). The diagram does indicate, however, that the 4-way valve is located in the working line, between the variable-displacement pump and the 1-inch rotary selector valve, and that the valve directs fluid to and from the rotary actuator.

Combination Diagrams

A combination drawing uses a combination of graphic, cutaway, and pictorial symbols. This drawing also includes all interconnecting piping.

FLUID POWER SYSTEMS

A fluid power system in which the fluid in the system remains pressurized from the pump (or regulator) to the directional control valve while the pump is operating is referred to as a closed-center system. In this type of system, any number of subsystems may be incorporated, with a separate directional control valve for each subsystem. The directional control valves are arranged in parallel so that system pressure acts equally on all control valves.

Another type of system that is sometimes used in hydraulically operated equipment is the open-center system. An open-center system has fluid flow but no internal pressure when the actuating mechanisms are idle. The pump circulates the fluid from the reservoir, through the directional control valves, and back to the reservoir. (See fig. 12-4, view A.) Like the closed-center system, the open-center system may have any number of subsystems, with a directional control valve for each subsystem. Unlike the closed-center system, the directional control valves of an open-center system are always connected in series with each other, an arrangement in which the system pressure line goes through each directional control valve. Fluid is always allowed free passage through each control valve and back to the reservoir until one of the control valves is positioned to operate a mechanism.

When one of the directional control valves is positioned to operate an actuating device, as shown in view B of figure 12-4, fluid is directed from the pump through one of the working lines to the actuator. With the control valve in this position, the flow of fluid through the valve to the reservoir is blocked. Thus, the pressure builds up in the system and moves the piston of the

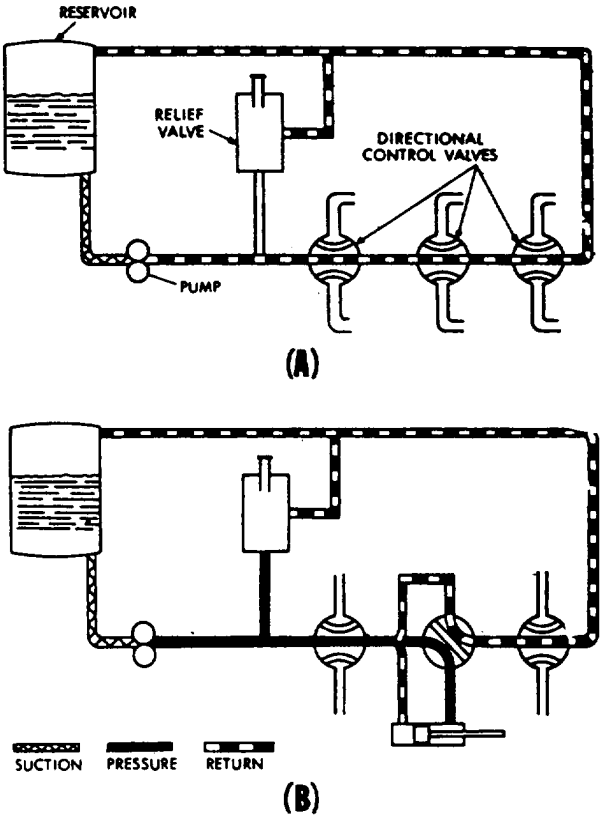


Figure 12-4.—Open-center hydraulic system.

actuating cylinder. The fluid from the other end of the actuator returns to the control valve through the opposite working line and flows back to the reservoir.

Several different types of directional control valves are used in the open-center system. One type is the manually engaged and manually disengaged. After this type of valve is manually moved to the operating position and the actuating mechanism reaches the end of its operating cycle, pump output continues until the system relief valve setting is reached. The relief valve then unseats and allows the fluid to flow back to the reservoir. The system pressure remains at the pressure setting of the relief valve until the directional control valve is manually returned to the neutral position. This action reopens the open-center flow and allows the system pressure to drop to line resistance pressure.

Another type of open-center directional control valve is manually engaged and pressure disengaged. This type of valve is similar to the valve discussed in the preceding paragraph; however, when the actuating mechanism reaches the end of its cycle and the pressure continues to

rise to a predetermined pressure, the valve automatically returns to the neutral position and, consequently, to open-center flow.

One of the advantages of the open-center system is that the continuous pressurization of the system is eliminated. Since the pressure is gradually built up after the directional control valve is moved to an operating position, there is very little shock from pressure surges. This provides a smooth operation of the actuating mechanisms; however, the operation is slower than the closed-center system in which the pressure is available the moment the directional control valve is positioned. Since most applications require instantaneous operation, closed-center systems are the most widely used.

HYDRAULIC POWER DRIVE SYSTEM

The hydraulic power drive has been used in the Navy for many years. Proof of its effectiveness is that it has been used to train and elevate nearly all caliber guns, from the 40-mm gun mount to the 16-inch turret. In addition to gun mounts and turrets, hydraulic power drives are used to position rocket launchers and missile launchers, and to drive and control such equipment as windlasses, capstans, and winches.

In its simplest form, the hydraulic power drive consists of the following:

1. The prime mover, which is the outside source of power used to drive the hydraulic pump
2. A variable-displacement hydraulic pump
3. A hydraulic motor
4. A means of introducing a signal to the hydraulic pump to control its output
5. Mechanical shafting and gearing that transmits the output of the hydraulic motor to the equipment being operated

Hydraulic power drives differ in some respects, such as size, method of control, and so forth. However, the fundamental operating principles are similar. The unit used in the following discussion of fundamental operating principles is representative of the hydraulic power drives used to operate the 5"/38 twin mounts.

Figure 12-5 shows the basic components of the train power drive. The electric motor is constructed with drive shafts at both ends. The forward shaft drives the A-end pump through reduction gears, and the after shaft drives the auxiliary pumps through the auxiliary reduction gears. The reduction gears are installed because

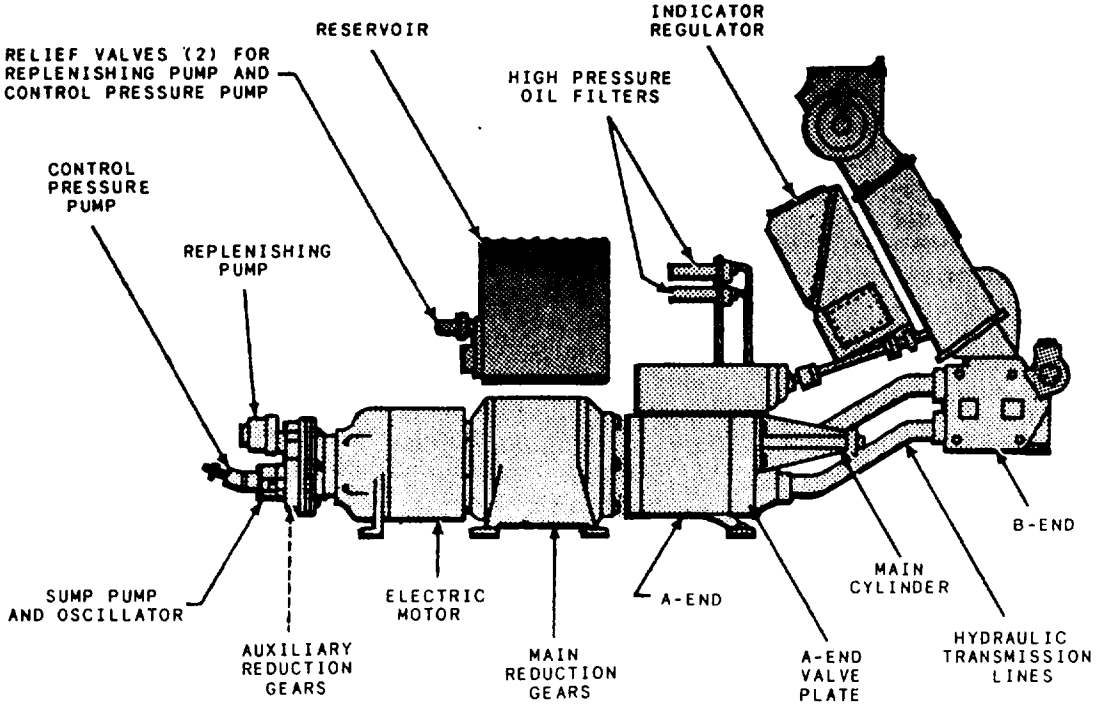


Figure 12-5.-Train power drive—components.

the pumps are designed to operate at a speed much slower than that of the motor.

The replenishing pump is a spur gear pump. Its purpose is to replenish fluid to the active system of the power drive. It receives its supply of fluid from the reservoir and discharges it to the B-end valve plate. This discharge of fluid from the pump is held at a constant pressure by the action of a pressure relief valve. (Because the capacity of the pump exceeds replenishing demands, the relief valve is continuously allowing some of the fluid to flow back to the reservoir.)

The sump pump and oscillator has a twofold purpose. It pumps leakage, which collects in the sump of the indicator regulator, to the expansion tank. Additionally, it transmits a pulsating effect to the fluid in the response pressure system. Oscillations in the hydraulic response system help eliminate static friction of valves, allowing hydraulic control to respond faster.

The control pressure pump supplies high-pressure fluid for the hydraulic control system, brake pistons, lock piston, and the hand-controlled clutch operating piston. The control pressure pump is a fixed-displacement, axial-piston type. An adjustable relief valve is used to limit the operating pressure at the outlet of the pump.

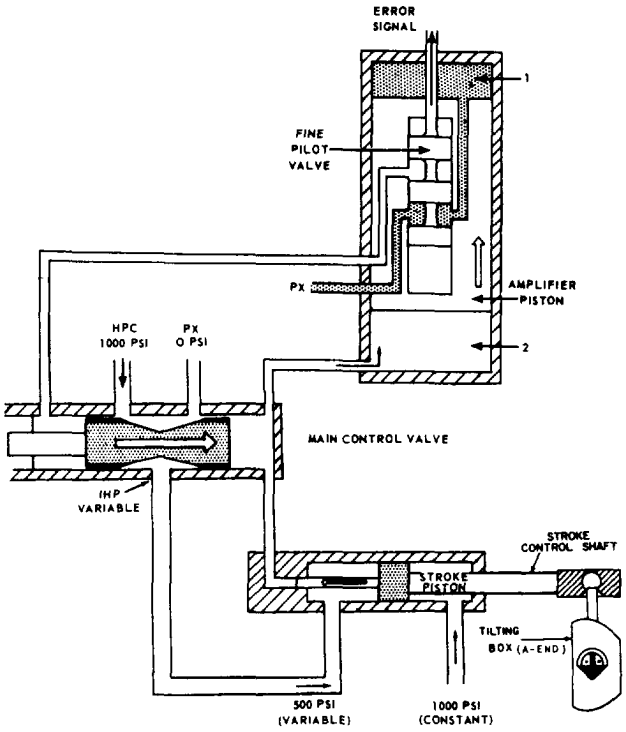


Figure 12–6.–Main cylinder assembly.

Control

For the purpose of this text, control constitutes the relationship between the stroke control shaft and the tilting box. The stroke control shaft is one of the piston rods of a double-acting piston-type actuating cylinder. This actuating cylinder and its direct means of control are referred to as the main cylinder assembly (fig. 12-6). It is the link between the hydraulic followup system and the power drive itself.

In hand control, the tilting box is mechanically positioned by gearing from the handwheel through the A-end control unit. In local and automatic control, the tilting box is positioned by the stroke control shaft. As shown in figure 12-6, the extended end of the control shaft is connected to the tilting box. Movement of the shaft will pivot the tilting box one way or the other; which, in turn, controls the output of the A-end of the transmission. The other end of the shaft is attached to the main piston. A shorter shaft is attached to the opposite side of the piston. This shaft is also smaller in diameter. Thus the working area of the left side of the piston is twice that of the area of the right side, as it appears in figure 12-6.

Intermediate high-pressure fluid (IHP) is transmitted to the left side of the piston, while high-pressure hydraulic fluid (HPC) is transmitted to the right side. The HPC is held constant at 1000 psi. Since the area of the piston upon which HPC acts is exactly one-half the area upon which IHP acts, the main piston is maintained in a fixed position when IHP is one-half HPC (500 psi). Whenever IHP varies from its normal value of 500 psi, the main piston will move, thus moving the tilting box.

Operation

Assume that a right train order signal is received. This will cause the pilot valve to be pulled upward. The fluid in the upper chamber of the amplifier piston can now flow through the lower land chamber of the fine pilot to exhaust. This will cause the amplifier piston to move upward, and the fluid in the right-hand chamber of the main control valve can flow into the lower chamber of the amplifier valve.

The main control valve will now move to the right, IHP will drop below 500 psi, and the stroke piston will move to the left. Movement of the

stroke piston will cause tilt to be put on the tilt plate, and the A-end will cause the mount to train right.

Figure 12-7 is a simplified block diagram showing the main element of the hydraulic power drive system under automatic control for clockwise and counterclockwise rotation.

There are two principal problems in positioning a gun to fire. One is to get an accurate gun-order signal. This problem is solved by the director-computer combination. The other problem is to transmit the director signal promptly to the gun so that the position and movements of the gun will be synchronized with the signals from the director.

The problem of transforming gun-order signals to mount movements is solved by the power drive and its control—the indicator regulator. The indicator regulator controls the power drive, and this, in turn, controls the movement of the gun.

The indicator regulator receives an initial electrical gun-order from the director-computer, compares it to the existing mount position, and sends an error signal to the hydraulic control mechanism in the regulator. The hydraulic control mechanism controls the flow to the stroke control shaft, which positions the tilting box in the A-end of the transmission. Its tilt controls the volume and direction of fluid pumped to the B-end and, therefore, the speed and direction of the drive shaft of the B-end. Through mechanical linkage, the B-end output shaft moves the gun in the direction determined by the signal. At the same time, B-end response is transmitted to the indicator regulator and continuously combines with incoming gun-order signals to give the error between the two. This error is modified hydraulically, according to the system of mechanical linkages and valves in the regulator. When the gun is lagging behind the signal, its movement is accelerated; and when it begins to catch up, its movement is slowed down so that it will not overrun excessively.

LANDING GEAR EMERGENCY SYSTEM

If the landing gear in a naval aircraft fails to extend to the down and locked position, the aircraft has an emergency method to extend the landing gear. This text will cover the nitrogen system.

The nitrogen storage bottle system is a one-shot system powered by nitrogen pressure stored in four compressed nitrogen bottles (fig. 12-8). When the landing gear control handle is used to actuate the emergency landing gear system, a cable between the control and the manually operated nitrogen bottle opens the emergency gear down release valve on the bottle. Nitrogen from this bottle actuates the release valves on the other three bottles so that they discharge. Nitrogen flows from the manually operated bottle, actuates the dump valves, and causes the shuttles within the shuttle valves on the

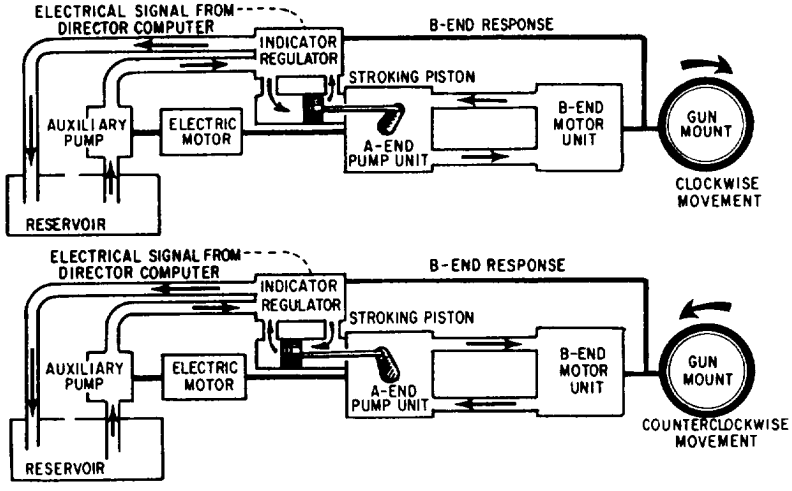


Figure 12-7.—Operation of the hydraulic power drive.

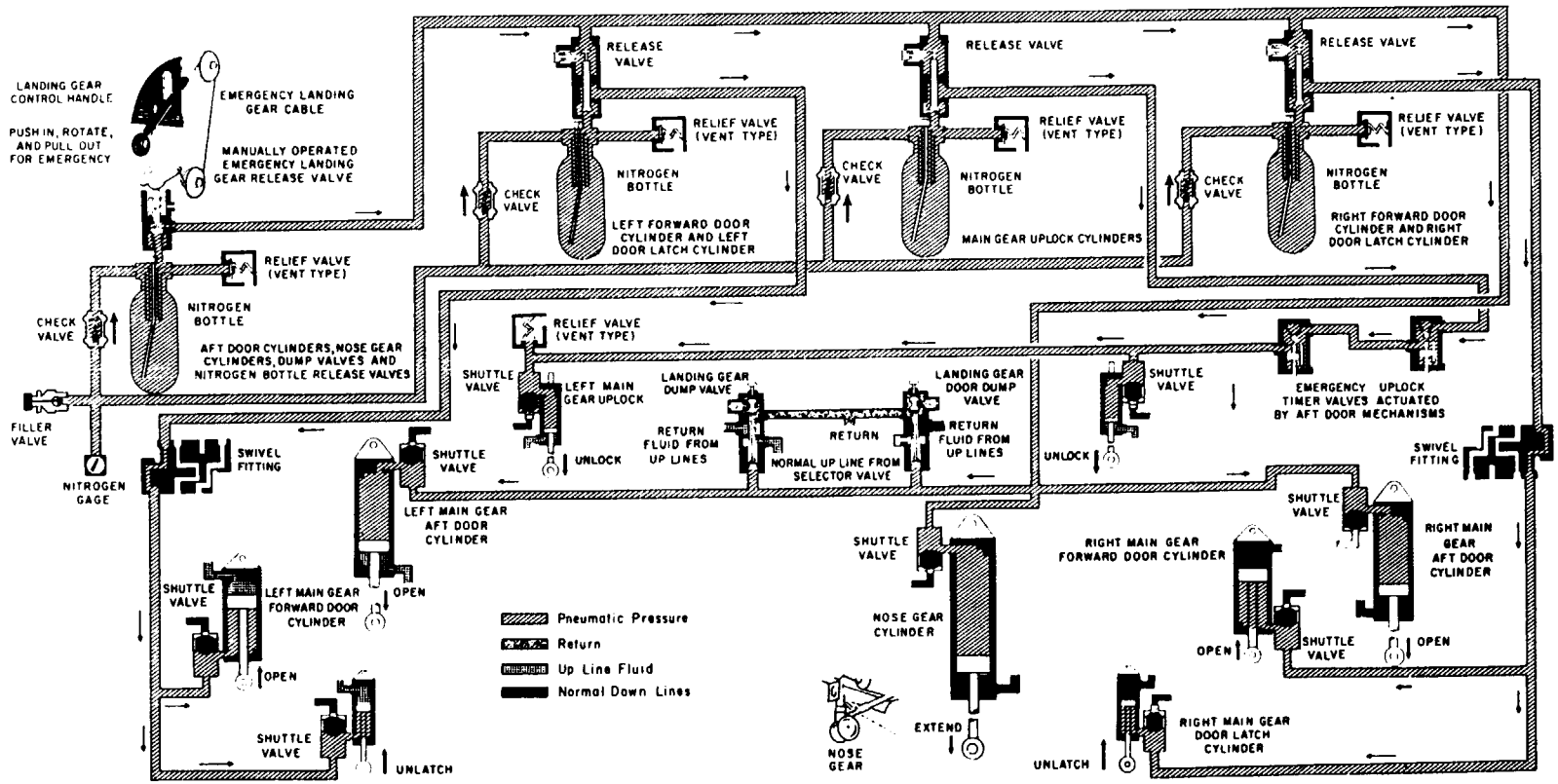


Figure 12-8.—Landing gear emergency extension system.

aft doors' cylinders and the shuttle valve on the nose gear cylinder to close off the normal port and operate these cylinders. The nose gear cylinder extends; this unlocks the uplock and extends the nose gear. The nitrogen flowing into the aft door cylinders opens the aft doors. Fluid on the close side of the door cylinder is vented to return through the actuated dump valves. Nitrogen from another bottle actuates the shuttle valves on the uplock cylinders. Nitrogen flows into the uplock cylinders and causes them to disengage the uplocks. As soon as the uplocks are disengaged, the main gear extends by the force of gravity. Fluid on the up side of the main gear cylinders is vented to return through the actuated dump valves, preventing a fluid lock.

JET BLAST DEFLECTORS

Jet blast deflectors (JBD) onboard aircraft carriers are raised and lowered by hydraulic cylinders through mechanical linkage. Two hydraulic cylinders are attached to each JBD panel shaft by crank assemblies. (See fig. 12-9.) The shaft is rotated by the push and pull operation of the hydraulic cylinders. Shaft rotation extends or retracts the linkage to raise or lower the JBD panels. This operation is designed so that in the event of a failure of one of the hydraulic cylinders, the other one will raise or lower the panels.

Figure 12-10 is a diagram of the hydraulic control system of a JBD during the raise cycle. Hydraulic fluid from the catapult hydraulic supply system is supplied to the JBD hydraulic system through an isolation valve and a filter to the 4-way control valve assembly. (The 4-way control valve assembly consists of a pilot-operated control valve, a direct- or solenoid-operated control valve, and a sequence valve, which is not shown.)

To raise the JBD, solenoid B of the 4-way control valve assembly is energized. The spools of the 4-way valve assembly shift, allowing medium-pressure hydraulic fluid to flow into port A of the hydraulic cylinder. The cylinders extend,

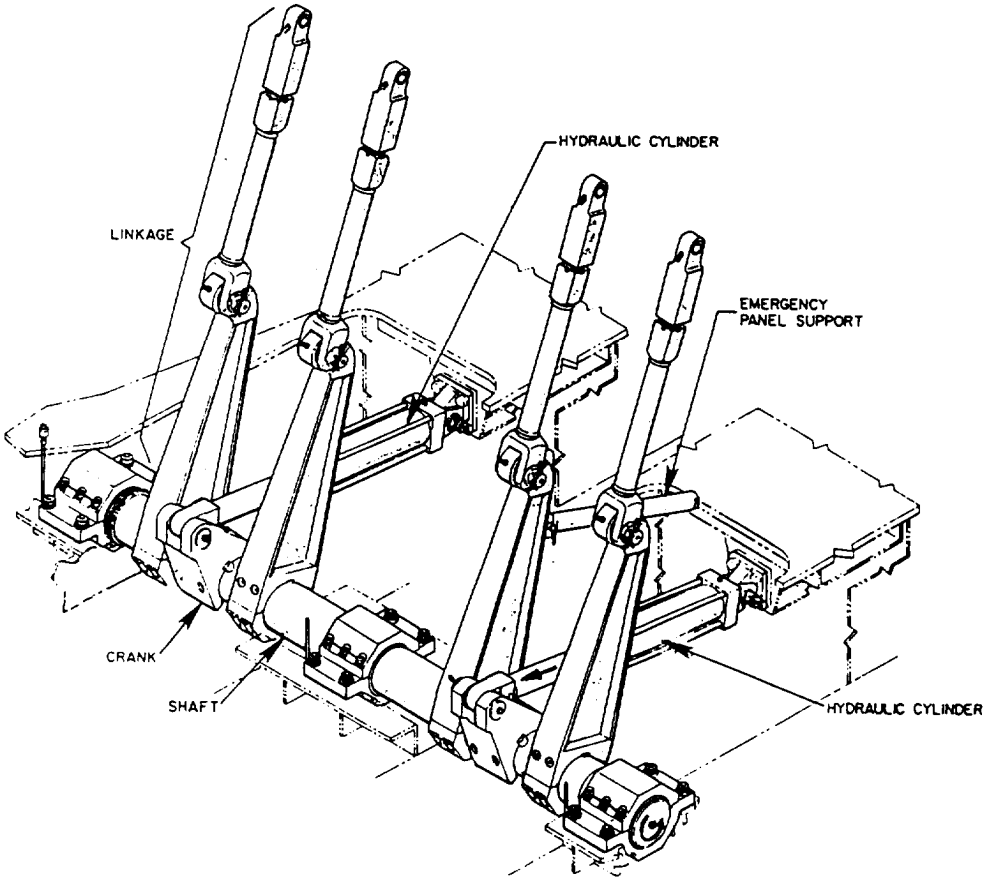


Figure 12-9.—Operating gear assembly (panels raised).

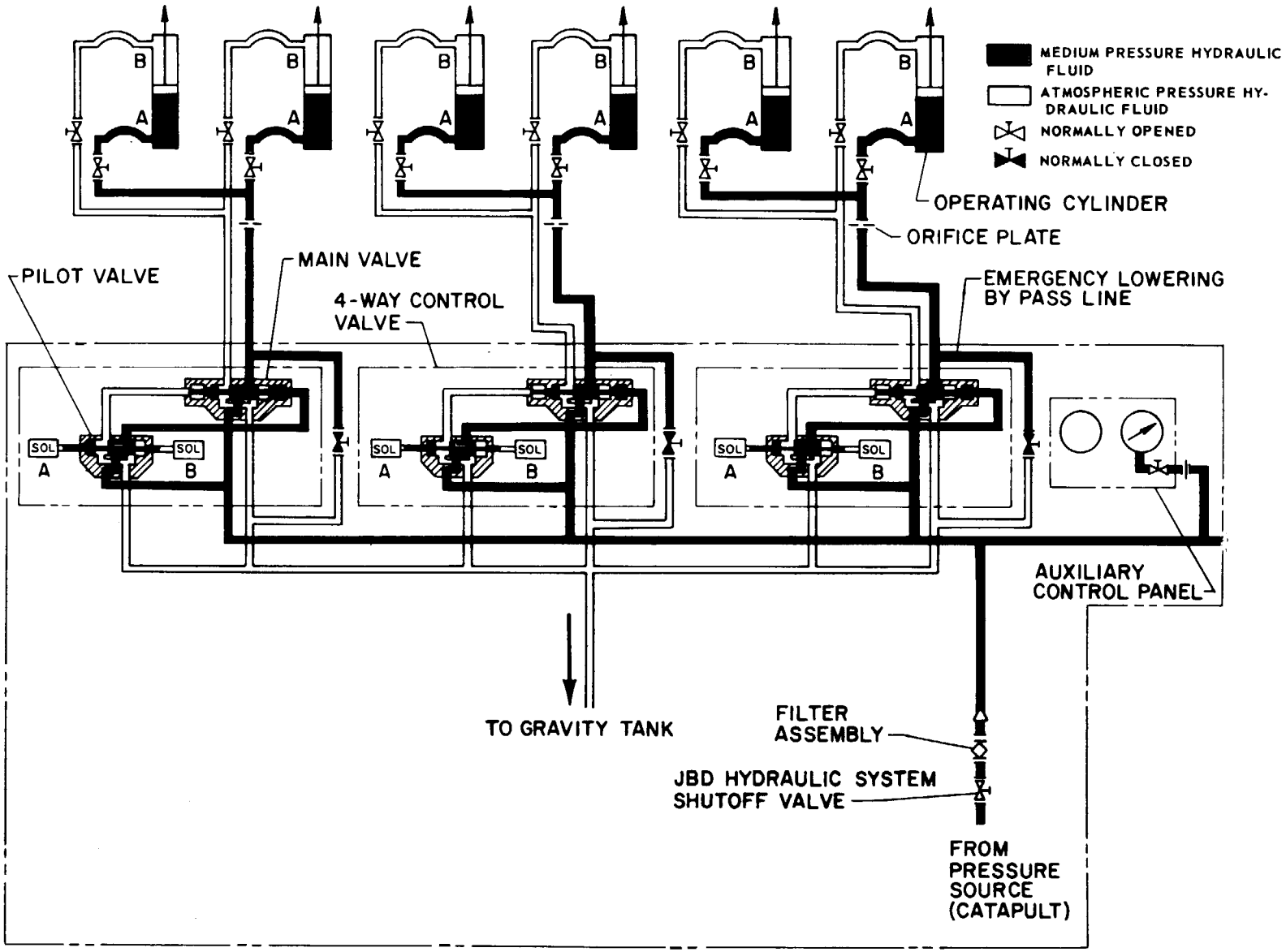


Figure 12-10.—Hydraulic system flow diagram, raise cycle.

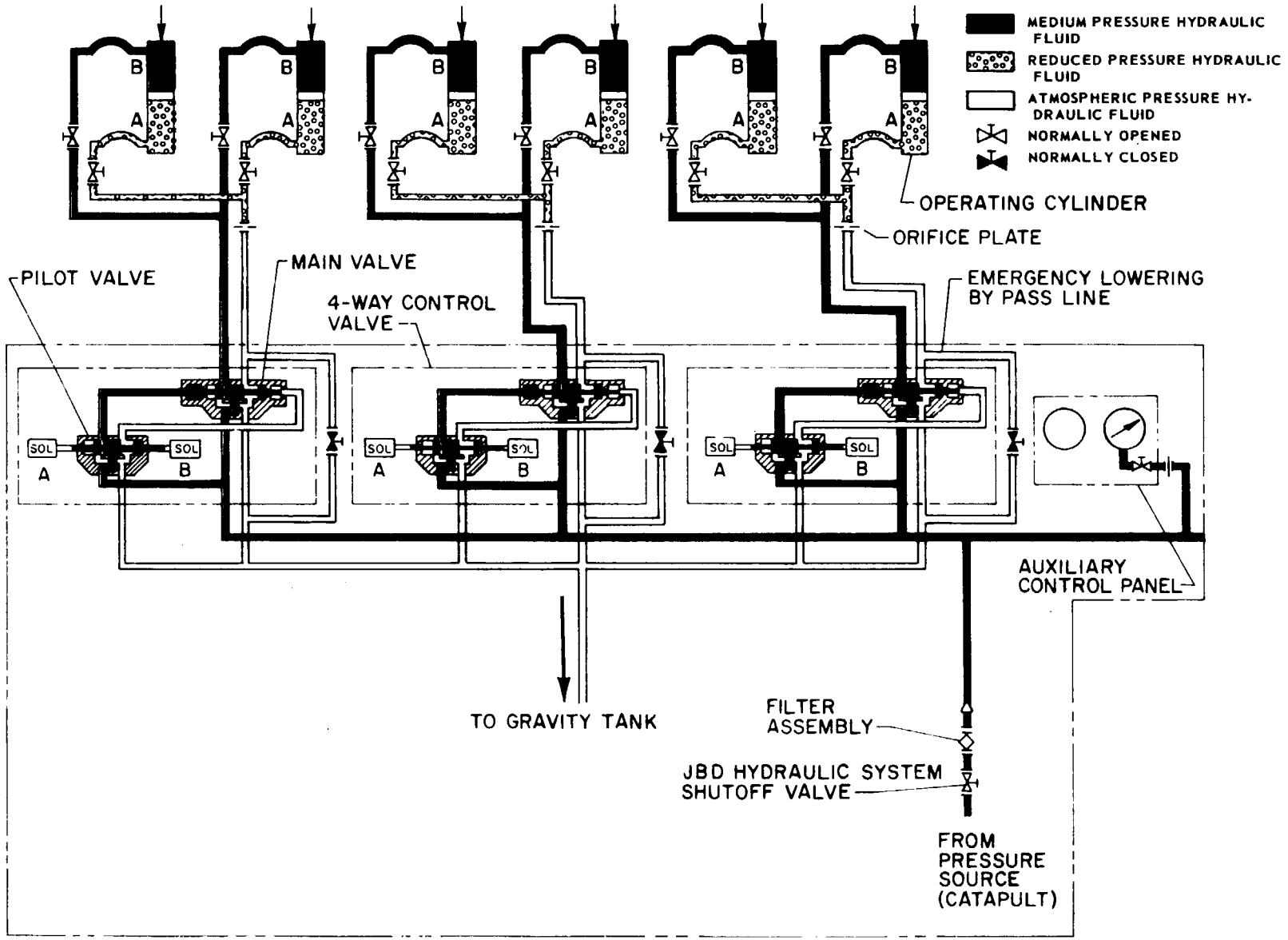


Figure 12-11.—Hydraulic system flow diagram, lower cycle.

pushing the crank assembly aft and rotating the shaft. The rotation of the shaft extends the operating gear linkage and raises the panel assemblies. Fluid from port B of the piston is directed through the 4-way valve assembly and back to the gravity tank.

To lower the JBD (fig. 12-11), solenoid A of the 4-way control valve assembly is energized. The spools of the 4-way valve assembly shift, allow medium-pressure hydraulic fluid to flow into port B of the hydraulic cylinder. The cylinders retract, pulling the crank assembly forward and rotating the shaft. The rotation of the shaft retracts the operating gear linkage and lowers the panel assemblies. Fluid from port A of the piston is directed through the 4-way valve assembly and back to the gravity tank.

To lower the JBD in the event of hydraulic control failure, each JBD panel is equipped with a manual bypass valve, which allows bypassing the 4-way control valve. This allows venting the hydraulic pressure from the “raise” side of the cylinder back to the gravity tank.

The three lines to port A of the hydraulic cylinders have orifice assemblies in them. These orifice assemblies control the flow of hydraulic fluid in both the raise and lower operations.

APPENDIX I

GLOSSARY

A part of this glossary has been extracted from the *American Standard Glossary of Terms for Fluid Power* (ASA B93.2-1965) with permission of the publisher, The National Fluid Power Association.

ABSOLUTE TEMPERATURE—The temperature measured using absolute zero as a reference. Absolute zero is –273.16°C or –459.69°F.

ACCELERATION—Time rate of change of velocity.

ACCUMULATOR—A device for storing liquid under pressure. It usually consists of a chamber separated into a gas compartment and a liquid compartment by a piston or diaphragm. An accumulator also serves to smooth out pressure surges in a hydraulic system.

ACTUATOR—A device that converts fluid power into mechanical force and motion.

ADDITIVE—A chemical compound or compounds added to a fluid to change its properties.

AIR, COMPRESSED—Air at any pressure greater than atmospheric pressure.

AMBIENT—Surrounding, such as ambient air, meaning surrounding air.

BAROMETER—An instrument that measures atmospheric pressure.

BERNOULLI'S PRINCIPLE—If a fluid flowing through a tube reaches a constriction, or narrowing of the tube, the velocity of the fluid flowing through the constriction increases and the pressure decreases.

BLEEDER, AIR—A bleeder for the removal of air.

BOYLE'S LAW—The absolute pressure of a fixed mass of gas varies inversely as the volume, provided the temperature remains constant.

CAVITATION—A localized gaseous condition within a liquid stream that occurs where the pressure is reduced to the vapor pressure.

CELSIUS—The temperature scale using the freezing point of water as zero and the boiling point as 100, with 100 equal divisions between, called degrees. This scale was formerly known as the centigrade scale.

CENTIGRADE—(See Celsius.)

CENTRIFUGAL FORCE—A force exerted on a rotating object in a direction outward from the center of rotation.

CHARLES'S LAW—If the pressure is constant, the volume of dry gas varies directly with the absolute temperature.

CHEMICAL CHANGE—A change that alters the composition of the molecules of a substance.

CIRCUIT—An arrangement of interconnected component parts.

COMPRESSIBILITY—The change in volume of a unit volume of a fluid when it is subjected to a unit change of pressure.

COMPRESSOR—A device that converts mechanical force and motion into pneumatic fluid power.

COMPUTER—A device capable of accepting information, applying prescribed processes to the information, and supplying the results of these processes.

CONDENSATION—The change from a gaseous (or vapor) state to a liquid state.

CONTAMINANT—Detrimental matter in a fluid.

CONTINUITY EQUATION—The mass rate of fluid flow into any fixed space is equal to the mass flow rate out. Hence, the mass flow rate of fluid past all cross sections of a conduit is equal.

CONTROL—A device used to regulate the function of a component or system.

CONTROL, CYLINDER—A control in which a fluid cylinder is the actuating device.

CONTROL, ELECTRIC—A control actuated electrically.

CONTROL, HYDRAULIC—A control actuated by a liquid.

CONTROL, MANUAL—A control actuated by the operator.

CONTROL, MECHANICAL—A control actuated by linkages, gears, screws, cams, or other mechanical elements.

CONTROL, PNEUMATIC—A control actuated by air or other gas pressure.

CONTROL, SERVO—A control actuated by a feedback system that compares the output with the reference signal and makes corrections to reduce the difference.

CONTROLS, PUMP—Controls applied to positive-displacement variable delivery pumps to adjust their volumetric output or direction of flow.

CONVERGENT—That which inclines and approaches nearer together, as the inner walls of a tube that is constricted.

COOLER—A heat exchanger, which removes heat from a fluid.

COOLER, AFTERCOOLER—A device that cools a gas after it has been compressed.

COOLER, INTERCOOLER—A device that cools a gas between the compressive steps of a multiple stage compressor.

COOLER, PRECOOLER—A device that cools a gas before it is compressed.

CORROSION—The slow destruction of materials by chemical agents and electromechanical reactions.

CYCLE—A single complete operation consisting of progressive phases starting and ending at the neutral position.

CYLINDER—A device that converts fluid power into linear mechanical force and motion. It usually consists of a movable element, such as a piston and piston rod, plunger, or ram, operating within a cylindrical bore.

CYLINDER, CUSHIONED—A cylinder with a piston-assembly deceleration device at one of both ends of the stroke.

CYLINDER, DOUBLE-ACTING—A cylinder in which fluid force can be applied to the movable element in either direction.

CYLINDER, DOUBLE-ROD—A cylinder with a single piston and a piston rod extending from each end.

CYLINDER, DUAL-STROKE—A cylinder combination that provides two working strokes.

CYLINDER, PISTON—A cylinder in which the movable element has a greater cross-sectional area than the piston rod.

CYLINDER, PLUNGER—A cylinder in which the movable element has the same cross-sectional area as the piston rod.

CYLINDER, SINGLE-ACTING—A cylinder in which the fluid force can be applied to the movable element in only one direction.

CYLINDER, SINGLE-ROD—A cylinder with a piston rod extending from one end.

CYLINDER, SPRING-RETURN—A cylinder in which a spring returns the piston assembly.

CYLINDER, TANDEM—Two or more cylinders with interconnected piston assemblies.

CYLINDER, TELESCOPING—A cylinder with nested multiple tubular rod segments which provide a long working stroke in a short retracted envelope.

DENSITY—The weight per unit volume of a substance.

DIAGRAM, COMBINATION—A drawing using a combination of graphical, cutaway, and pictorial symbols.

DIAGRAM, CUTAWAY—A drawing showing principal internal parts of all components, controls, and actuating mechanisms, all interconnecting lines and functions of individual components.

DIAGRAM, GRAPHICAL—A drawing or drawings showing each piece of apparatus including all interconnecting lines by approved standard symbols.

DIAGRAM, PICTORIAL—A drawing showing each component in its actual shape according to the manufacturer's installation.

DIAGRAM, SCHEMATIC—(See Diagram, graphical.)

DIAPHRAGM—A dividing membrane or thin partition.

DIFFUSER—A duct of varying cross section designed to convert a high-speed gas flow into low-speed at an increased pressure.

DISPLACEMENT—The volume of fluid that can pass through a pump, motor, or cylinder in a single revolution or stroke.

DIVERGENT—Moving away from each other, as the inner wall of a tube that flares outward.

EFFICIENCY—The ratio of the output power to the input power, generally expressed as a percentage.

ENERGY—The ability or capacity to do work.

EQUILIBRIUM—A state of balance between opposing forces or actions.

FAHRENHEIT—The temperature scale using the freezing point of water as 32 and the boiling point as 212, with 180 equal divisions between, called degrees.

FEEDBACK—A transfer of energy from the output of a device to its input.

FILTER—A device whose primary function is the retention by a porous media of insoluble contaminants from a fluid.

FILTER ELEMENT—The porous device that performs the actual process of filtration.

FILTER MEDIA—The porous materials that perform the actual process of filtration.

FILTER MEDIA, SURFACE—Porous materials that primarily retain contaminants on the influent face.

FLASH POINT—The temperature to which a liquid must be heated under specified conditions of the test method to give off sufficient vapor to form a mixture with air that can be ignited momentarily by a specified flame.

FLOW, LAMINAR—A flow situation in which fluid moves in parallel layers (also referred to as streamline flow).

FLOW, METERED—Flow at a controlled rate.

FLOW, TURBULENT—A flow situation in which the fluid particles move in a random manner.

FLOW RATE—The volume, mass, or weight of a fluid passing through any conductor per unit of time.

FLOWMETER—An instrument used to measure quantity or the flow rate of a fluid motion.

FLUID—A liquid or a gas.

FLUID FLOW—The stream or movement of a fluid, or the rate of its movement.

FLUID FRICTION—Friction due to the viscosity of fluids.

FLUID, FIRE-RESISTANT—A fluid difficult to ignite, which shows little tendency to propagate flame.

FLUID, HYDRAULIC—A fluid suitable for use in a hydraulic system.

FLUID, PETROLEUM—A fluid composed of petroleum oil. It may contain additives.

FLUID, PHOSPHATE ESTER BASE—A fluid that contains a phosphate ester as one of the major components.

FLUID, SILICONE—A fluid composed of silicones. It may contain additives.

FLUID, WATER-GLYCOL—A fluid whose major constituents are water and one or more glycols or polyglycols.

FLUID STABILITY—Resistance of a fluid to permanent change in properties.

FLUID POWER—Energy transmitted and controlled through the use of fluids under pressure.

FLUID POWER SYSTEM—A system that transmits and controls power through use of a pressurized fluid within an enclosed circuit.

FOOT-POUND—The amount of work accomplished when a force of 1 pound produces a displacement of 1 foot.

FORCE—The action of one body on another tending to change the state of motion of the body acted upon.

FREE FLOW—Flow that encounters negligible resistance.

FRICTION—The action of one body or substance rubbing against another, such as fluid flowing against the walls of pipe; the resistance to motion caused by this rubbing.

FRICTION PRESSURE DROP—The decrease in the pressure of a fluid flowing through a passage attributable to the friction between the fluid and the passage walls.

GAS—The form of matter that has neither a definite shape nor a definite volume.

GASKET—A class of seals that provides a seal between two stationary parts.

GAUGE—An instrument or device for measuring, indicating, or comparing a physical characteristic.

GAUGE PRESSURE—Pressure above atmospheric pressure.

GAUGE SNUBBER—A device installed in the line to the pressure gauge used to dampen pressure surges and thus provide a steady reading and a protection for the gauge.

GAUGE, BELLOWS—A gauge in which the sensing element is a convoluted closed cylinder. A pressure differential between the outside and the inside causes the cylinder to expand or contract axially.

GAUGE, BOURDON TUBE—A pressure gauge in which the sensing element is a curved tube that tends to straighten out when subjected to internal fluid pressure.

GAUGE, DIAPHRAGM—A gauge in which the sensing element is relatively thin and its inner portion is free to deflect with respect to its periphery.

GAUGE, PRESSURE—A gauge that indicates the pressure in the system to which it is connected.

GAUGE, VACUUM—A pressure gauge for pressures less than atmospheric.

GRAVITY—The force that tends to draw all bodies toward the center of the earth. The weight of a body is the resultant of gravitational force acting on the body.

HEAD—The height of a column or body of fluid above a given point expressed in linear units. Head is often used to indicate gauge pressure. Pressure is equal to the height times the density of the fluid.

HEAD, FRICTION—The head required to overcome the friction at the interior surface of a conductor and between fluid particles in motion. It varies with flow, size, type, and condition of conductors and fittings, and fluid characteristics,

HEAD, STATIC—The height of a column or body of fluid above a given point.

HEAD, VELOCITY—The equivalent head through which the liquid would have to fall to attain a given velocity. Mathematically it is equal to the square of the velocity (in feet) divided by 64.4 feet per second square.

HEAT EXCHANGER—A device that transfers heat through a conducting wall from one fluid to another.

HYDRAULICS—Engineering science pertaining to liquid pressure and flow.

HYDROMETER—An instrument for determining the specific gravities of liquids.

HYDROPNEUMATICS—Pertaining to the combination of hydraulic and pneumatic fluid power.

HYDROSTATICS—Engineering science pertaining to the energy of liquids at rest.

IMPACT PRESSURE—The pressure of a moving fluid brought to rest that is in excess of the pressure the fluid has when it does not flow; that is, total pressure less static pressure. Impact pressure is equal to dynamic pressure in incompressible flow; but in compressible flow, impact pressure includes the pressure change owing to the compressibility effect.

IMPINGEMENT—The striking or dashing upon with a clash or sharp collision, as air impinging upon the rotor of a turbine or motor.

IMPULSE TURBINE—A turbine driven by a fluid at high velocity under relatively low pressure.

INERTIA—The tendency of a body at rest to remain at rest, and a body in motion to continue to move at a constant speed along a straight line, unless the body is acted upon in either case by an unbalanced force.

INHIBITOR—Any substance which slows or prevents chemical reactions such as corrosion or oxidation.

INVERSE PROPORTION—The relation that exists between two quantities when an increase in one of them produces a corresponding decrease in the other.

KELVIN SCALE—The temperature scale using absolute zero as the zero point and divisions that are the same size as centigrade degrees.

KINETIC ENERGY—The energy that a substance has while it is in motion.

KINETIC THEORY—A theory of matter that assumes that the molecules of matter are in constant motion.

LINE—A tube, pipe, or hose that is used as a conductor of fluid.

LIQUID—A form of matter that has a definite volume but takes the shape of its container.

LOAD—The power that is being delivered by any power-producing device. The equipment that uses the power from the power-producing device.

LUBRICATOR—A device that adds controlled or metered amounts of lubricant into a fluid power system.

MANIFOLD—A type of fluid conductor that provides multiple connections ports.

MANOMETER—A differential pressure gauge in which pressure is indicated by the height of a liquid column of known density. Pressure is equal to the difference in vertical height between two connected columns multiplied by the density of the manometer liquid. Some forms of manometers are U tube, inclined tube, well, and bell types.

MATTER—Any substance that occupies space and has weight.

MECHANICAL ADVANTAGE—The ratio of the resisting weight to the acting force. The ratio of the distance through which the force is exerted divided by the distance the weight is raised.

METER-IN—To regulate the amount of fluid into a system or an actuator.

METER-OUT—To regulate the flow of fluid from a system or actuator.

MICRON—A millionth of a meter or about 0.00004 inch.

MOLECULE—A small natural particle of matter composed of two or more atoms.

MOTOR—A device that converts fluid power into mechanical force and motion. It usually provides rotary mechanical motion.

MOTOR, FIXED-DISPLACEMENT—A motor in which the displacement per unit of output motion cannot be varied.

MOTOR, LINEAR—(See Cylinder.)

MOTOR, ROTARY—A motor capable of continuous rotary motion.

MOTOR, ROTARY LIMITED—A rotary motor having limited motion.

MOTOR, VARIABLE-DISPLACEMENT—A motor in which the displacement per unit of output motion can be varied.

NEOPRENE—A synthetic rubber highly resistant to oil, light, heat, and oxidation.

NEUTRALIZATION NUMBER—A measure of the total acidity or basicity of an oil; this includes organic or inorganic acids or bases or a combination of them.

OXIDATION—The process by which oxygen unites with some other substance, causing rust or corrosion.

PACKING—A class of seal that is used to provide a seal between two parts of a unit which move in relation to each other.

PASCAL'S LAW—A pressure applied to a confined fluid at rest is transmitted with equal intensity throughout the fluid.

PERIPHERY—The outside surface, especially that of a rounded object or body.

PIPE—A type of fluid line whose dimensions are designated by nominal (approximate) inside diameter and wall thickness.

PNEUMATICS—Engineering science pertaining to gaseous pressure and flow.

PORT—An internal or external terminus of a passage in a component.

POTENTIAL ENERGY—The energy a substance has because of its position, its condition, or its chemical composition.

POUR POINT—The lowest temperature at which a liquid will flow under specified conditions.

POWER UNIT—A combination of pump, pump drive, reservoir, controls, and conditioning components which may be required for its application.

POWER—The rate of doing work or the rate of expanding energy.

PRESSURE—The amount of force distributed over each unit of area, usually expressed in pounds per square inch.

PRESSURE, ABSOLUTE—The sum of atmospheric and gauge pressures.

PRESSURE, ATMOSPHERIC—Pressure exerted by the atmosphere at any specific location.

PRESSURE, BACK—The pressure encountered on the return side of a system.

PRESSURE, DIFFERENTIAL—The difference in pressure between any two points of a system or a component.

PRESSURE, HEAD—The pressure due to the height of a column or body of fluid. It is usually expressed in feet.

PRESSURE, OPERATING—The pressure at which a system operates.

PRESSURE, PRECHARGE—The pressure of compressed gas in an accumulator prior to the admission of a liquid.

PRESSURE, PROOF—The nondestructive test pressure in excess of the maximum rated operating pressure.

PRESSURE, STATIC—The pressure in a fluid at rest.

PRESSURE SWITCH—An electrical switch operated by the increase or decrease of fluid pressure.

PRIME MOVER—The source of mechanical power used to drive the pump or compressor.

PUMP—A device that converts mechanical force and motion into hydraulic fluid power.

PUMP, AXIAL PISTON—A pump having multiple pistons disposed with their axes parallel.

PUMP, CENTRIFUGAL—A pump that produces fluid velocity and converts it to pressure head.

PUMP, FIXED-DISPLACEMENT—A pump in which the displacement per cycle cannot be varied.

PUMP, RADIAL PISTON—A pump having multiple pistons disposed radially actuated by an eccentric element.

PUMP, VARIABLE-DISPLACEMENT—A pump in which the volume of fluid per cycle can be varied.

RANKINE SCALE—A thermometer scale based on absolute zero of the Fahrenheit scale, in which the freezing point of water is approximately 492°R.

RATIO—The value obtained by dividing one number by another, indicating their relative proportions.

RECEIVER—A container in which gas is stored under pressure as a supply source for pneumatic power.

RECIPROCATING—Moving back and forth, as a piston reciprocating in a cylinde.,

RESERVOIR—A container for storage of liquid in a fluid power system.

RESPONSE TIME—The time lag between a signal input and the resulting change of output.

RESTRICTOR—A device that reduces the cross-sectional flow area.

RESTRICTOR, ORIFICE—A restrictor, the length of which is relatively small with respect to its cross-sectional area. The orifice may be fixed or variable. Variable types are noncompensated, pressure compensated, or pressure and temperature compensated.

RETURN LINE—A line used for returning fluid back into the reservoir or atmosphere.

SEPARATOR—A device whose primary function is to isolate undesirable fluids and or contaminants by physical properties other than size.

SERVO—A device used to convert a small movement into a greater movement of force.

SOLID—The form of matter that has a definite shape and a definite volume.

SPECIFIC GRAVITY—The ratio of the weight of a given volume of a substance to the weight of an equal volume of some standard substance.

STEADY FLOW—A flow in which the velocity, pressure, and temperature at any point in the fluid do not vary with time.

STRAINER—A coarse filter.

STOKE—The standard unit of kinematic viscosity in the cgs system. It is expressed in square centimeters per second; 1 centistoke equals 0.01 stoke.

STUFFING BOX—A cavity and closure with manual adjustment for a sealing device.

SUPPLY LINE—A line that conveys fluid from the reservoir to the pump.

SURGE—A momentary rise of pressure in a circuit.

SYNCHRONIZE—To make two or more events or operations occur at the proper time with respect to each other.

SYNTHETIC MATERIAL—A complex chemical compound that is artificially formed by the combining of two or more simpler compounds or elements.

TANK—A container for the storage of fluid in a fluid power system.

THEORY—A scientific explanation, tested by observations and experiments.

THERMAL EXPANSION—The increase in volume of a substance due to temperature change.

TORQUE—A force or combination of forces that produces or tends to produce a twisting or rotary motion.

TUBING—A type of fluid line whose dimensions are designated by actual measured outside diameter and by actual measured wall thickness.

TURBINE—A rotary motor actuated by the reaction, impulse, or both, of a flow of pressurized fluid.

VALVE—A device that controls fluid flow direction, pressure, or flow rate.

VALVE, CHECK—A directional control valve that permits flow of fluid in only one direction.

VALVE, COUNTERBALANCE—A pressure control valve that maintains back pressure to prevent a load from falling.

VALVE, DIRECTIONAL CONTROL—A valve whose primary function is to direct or prevent flow through selected passages.

VALVE, FLOW CONTROL—A valve whose primary function is to control flow rate.

VALVE, HYDRAULIC—A valve for controlling liquid.

VALVE, PILOT—A valve used to operate another valve or control.

VALVE, PNEUMATIC—A valve for controlling gas.

VALVE, PRESSURE REDUCING—A pressure control valve whose primary function is to limit outlet pressure.

VALVE, PRIORITY—A valve that directs flow to one operating circuit at a fixed rate and directs excess flow to another operating circuit.

VALVE, RELIEF—A pressure control valve whose primary function is to limit system pressure.

VALVE, SELECTOR—A directional control valve whose primary function is to selectively interconnect two or more ports.

VALVE, SEQUENCE—A valve whose primary function is to direct flow in a predetermined sequence.

VALVE, SERVO—A directional control valve that modulates flow or pressure as a function of its input signal.

VALVE, SHUTOFF—A valve that operates fully open or fully closed.

VALVE, UNLOADING—A pressure control valve whose primary function is to permit a pump or compressor to operate at minimum load.

VELOCITY—The rate of motion in a particular direction. The velocity of fluids is usually expressed in feet per second.

VENTURI—A tube having a narrowing throat or constriction to increase the velocity of fluid flowing through it. The flow through the venturi causes a pressure drop in the smallest section, the amount being a function of the velocity of flow.

VISCOSITY—A measure of the internal friction or resistance of a fluid to flow.

VISCOSITY INDEX—A measure of the viscosity-temperature characteristics of a fluid as referred to that of two arbitrary reference fluids.

VISCOSITY, SAYBOLT UNIVERSAL SECONDS (SUS)—The time in seconds for 60 milliliters of oil to flow through a standard orifice at a given temperature.

VISCOSITY, KINEMATIC—The absolute viscosity divided by the density of the fluid. It is usually expressed in centistokes.

VOLUME OF FLOW—The quantity of fluid that passes a certain point in a unit of time. The volume of flow is usually expressed in gallons per minute for liquids and cubic feet per minute for gases.

WORK—The transference of energy from one body or system to another. That which is accomplished by a force acting through a distance.

APPENDIX II

MECHANICAL SYMBOLS OTHER THAN AERONAUTICAL FOR FLUID POWER DIAGRAMS

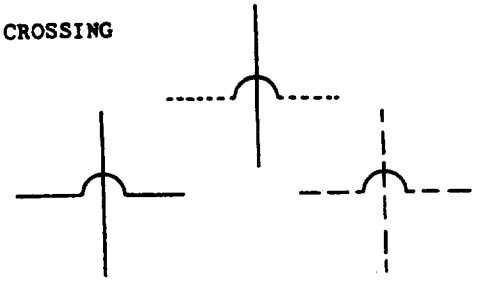
LINES

LINES, WORKING

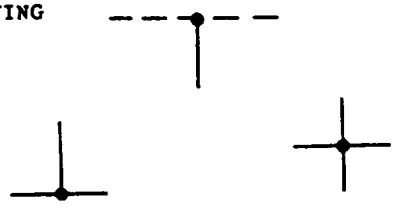
LINES, PILOT

LINES, LIQUID DRAIN OR AIR EXHAUST

LINES, CROSSING

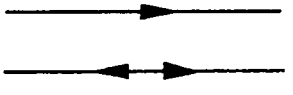


LINES, JOINING



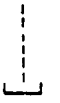
LINES, FLEXIBLE

FLOW, DIRECTION OF



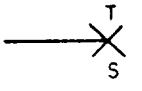
LINES TO RESERVOIR BELOW FLUID LEVEL

ABOVE FLUID LEVEL

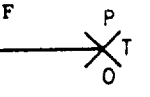


PLUG OR PLUGGED CONNECTION

TESTING STATION

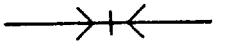


FLUID POWER TAKE-OFF STATION

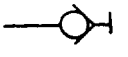


RESTRICTION, FIXED

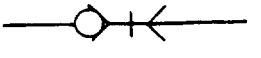
QUICK DISCONNECT WITHOUT CHECKS



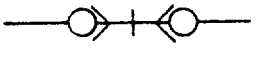
WITH CHECKS DISCONNECTED



WITH ONE CHECK



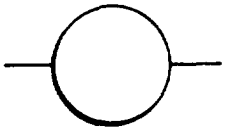
WITH TWO CHECKS



PUMPS, COMPRESSORS & ROTARY MOTORS

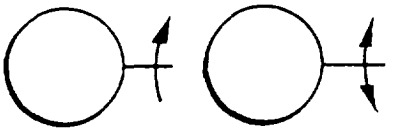
BASIC SYMBOL ENVELOPE

PORTS



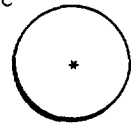
LINES OUTSIDE ENVELOPE ARE NOT PART OF SYMBOL, BUT REPRESENT FLOW LINES CONNECTED THERETO.

SHAFTS, ROTATING



ARROW INDICATES DIRECTION OF ROTATION BY ASSUMING IT IS ON NEAR SIDE OF SHAFT.

PUMPS, HYDRAULIC

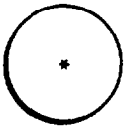


APPROPRIATE SYMBOLS SHALL BE ADDED TO INDICATE SHAFTS, CONNECTING LINES, AND METHOD OF CONTROL.

*TYPE OF PUMP SHALL BE INDICATED WITHIN BASIC SYMBOL BY APPROPRIATE LETTERS LISTED BELOW.

PF FIXED DISPLACEMENT
PK KINETIC - CENTRIFUGAL
PV VARIABLE DISPLACEMENT

COMPRESSORS, AIR

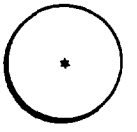


APPROPRIATE SYMBOLS SHALL BE ADDED TO INDICATE SHAFTS, CONNECTING LINES, AND METHOD OF CONTROL.

*TYPE OF COMPRESSOR SHALL BE INDICATED WITHIN BASIC SYMBOL BY APPROPRIATE LETTERS LISTED BELOW.

CF FIXED DISPLACEMENT
CK KINETIC

FLUID MOTORS, ROTARY



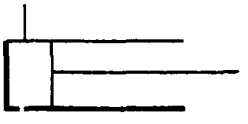
APPROPRIATE SYMBOLS SHALL BE ADDED TO INDICATE SHAFTS, CONNECTING LINES, AND METHOD OF CONTROL.

*TYPE OF MOTOR SHALL BE INDICATED WITHIN BASIC SYMBOL BY APPROPRIATE LETTERS LISTED BELOW.

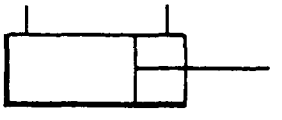
MF FIXED DISPLACEMENT
MO OSCILLATING
MV VARIABLE DISPLACEMENT

CYLINDERS

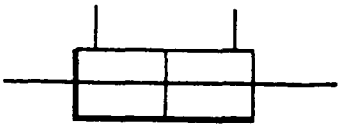
SINGLE ACTING



DOUBLE ACTING SINGLE END ROD



DOUBLE END ROD



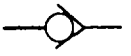
RESERVOIRS

VENTED

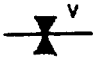
PRESSURIZED

RECEIVER FOR AIR OR OTHER GASES

VALVE

VALVE, CHECK 

VALVE, RESTRICTION, CHOKE VARIABLE VISCOUS 

VALVE, RESTRICTION, ORIFICE VARIABLE NON-VISCOUS 

VALVE, BASIC SYMBOL (INSERT MODEL NO. FOR SPECIAL VALVES) 

METHOD OF INDICATING INTERNAL FLOW 

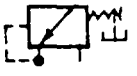
VALVE EXAMPLES

VALVE, MANUAL SHUT OFF 

VALVE, RELIEF MAXIMUM PRESSURE 

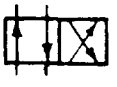
VALVE, RELIEF REMOTELY OPERATED 

VALVE, SEQUENCE DIRECTLY OPERATED 

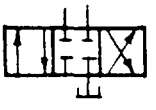
VALVE, PRESSURE REDUCING 

VALVE, SHUT OFF 2 POSITION-2 CONNECTION 

VALVE, DIRECTIONAL 2 POSITION-3 CONNECTION 

VALVE, DIRECTIONAL 2 POSITION-4 CONNECTION 

VALVE, DIRECTIONAL 3 POSITION-4 CONNECTION OPEN CENTER 

VALVE, DIRECTIONAL 3 POSITION-4 CONNECTION CLOSED CENTER 

TYPE OF CONTROL

CONTROL, BASIC SYMBOL 

CONTROL, CENTRIFUGAL 

CONTROL, COMPENSATOR 

CONTROL, COMPENSATOR PRESSURE 

CONTROL, COMPENSATOR TEMPERATURE 

CONTROL, CYLINDER 

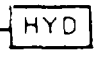
CONTROL, DETENT 

CONTROL, MANUAL 

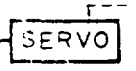
CONTROL, MECHANICAL 

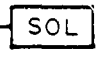
CONTROL, MOTOR ELECTRIC 

CONTROL, MOTOR HYDRAULIC 

CONTROL, PILOT HYDRAULIC 

CONTROL, PILOT AIR 

CONTROL, SERVO 

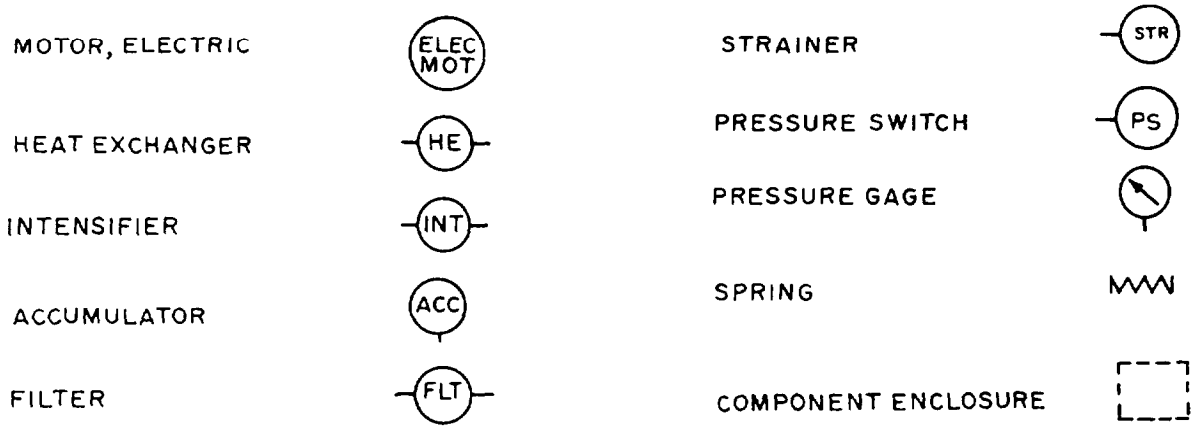
CONTROL, SOLENOID 

CONTROL, SOLENOID HYD. PILOT OPERATED 

CONTROL, THERMAL 

CONTROL, PILOT HYD. DIFFERENTIAL AREA 

MISCELLANEOUS UNITS



APPENDIX III

AERONAUTICAL MECHANICAL SYMBOLS FOR FLUID POWER DIAGRAMS

TUBE AND HOSE LINES

BRAKE

DOWN (OR CLOSE)

EMERGENCY PRESSURE

HOSE CONNECTION (RIGID TUBING)

HOSE, FLEXIBLE

RETURN

SUPPLY FLUID (PUMP SUCTION)

SUCTION GRAVITY

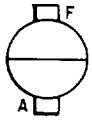
SUPPLY PRESSURE

UP (OR OPEN)

VENT

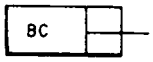
EQUIPMENT

ACCUMULATOR

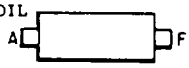


AIR BOTTLE, EMERGENCY

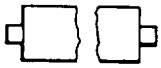
BRAKE CONTROL



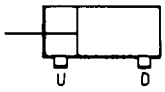
BUNGEE, AIR-OIL



COUPLING, SELF-SEALING

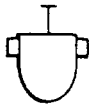


CYLINDER, ACTUATING

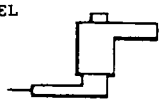


DEBOOSTER, BRAKE

FILTER OR STRAINER



FITTING, SWIVEL

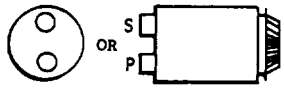


GAUGE, PRESSURE

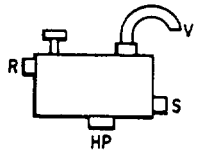
GAUGE AND SNUBBER, PRESSURE

PUMP, HAND

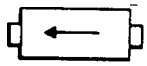
PUMP, POWER DRIVEN



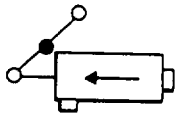
RESERVOIR



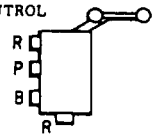
VALVE, CHECK, AUTOMATIC



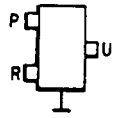
VALVE, CHECK, MANUAL



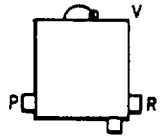
VALVE, BRAKE CONTROL



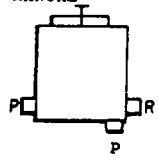
VALVE, GUN CHARGER CONTROL



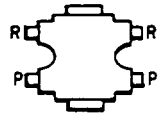
VALVE, PRESSURE REGULATING (UNLOADING) AUTOMATIC



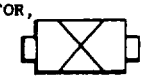
VALVE, PRESSURE REGULATING (UNLOADING) MANUAL



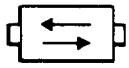
VALVE, RELIEF



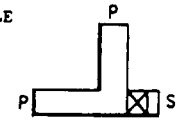
VALVE, RESTRICTOR, BOTH WAYS



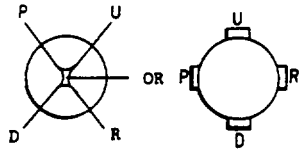
VALVE, RESTRICTOR, PARTIAL ONE-WAY



VALVE, SHUTTLE



VALVE OR SELECTOR, DIRECTIONAL CONTROL



ALPHABETIC CODE

A - AIR

B - BRAKE

BC - BRAKE CONTROL

D - DOWN (OR CLOSE)

F - FLUID (LIQUID)

HP - HANDPUMP

P - PRESSURE

R - RETURN

S - SUCTION (OR SUPPLY)

U - UP (OR OPEN)

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